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BRIEFING PAPER

EFFECTS OF LEGAL AND ILLEGAL CATCH ON THE ABUNDANCE OF SELECTED FISH IN THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Resources Agency, State of California
BAY-DELTA OVERSIGHT COUNCIL

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Preface

This briefing package details the benefits and impacts that legal and illegal harvest of specific species of concern may have on anadromous and resident fish of the Bay/Delta Estuary. This discussion was prepared for BDOC through the joint efforts of several resource managers within the Department of Fish and Game with editorial assistance from BDOC staff.

A second purpose of this briefing package is to provide a forum for other perspectives regarding the benefits and impacts on the Estuary's fishery resources. BDOC staff has solicited these view points from both commercial fishing interests and from water resource managers in an attempt to display the full spectrum of opinion on this topic. To facilitate the reader's understanding of the issues, these perspectives are presented at the conclusion of the major sections under the heading "Other View Points".

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INTRODUCTION

The Bay-Delta Oversight Council (Council), at its April 15, 1994 meeting, adopted a general objective for Biological Resources which states:

"Improve and sustain biological resources dependent on the estuarine ecosystem."

The Council will evaluate action options identified to achieve that objective and will combine **them** with options **needed** to address other objectives into comprehensive **solution alternatives that will** protect and enhance the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Estuary). In order to effectively evaluate action options and ultimately the anticipated success of achieving the general objective, factors such as how the legal and illegal harvest of fish have and are affecting the Estuary must be considered. This document **has been** prepared in response to a request from **the** Council for additional information on the harvest of fish in **and beyond** the Estuary and its potential effect on the Estuary's aquatic resources.

The Council, its Biological Technical Advisory Committees, **and other interested parties,** can use the data **included in this report** and other information for several purposes: first, to better understand the causes of the significant decline in **Estuary** fishery resources since the 1970s; second, to determine if measures to control harvest, particularly illegal harvest, need to be implemented or **intensified** to achieve the Council's objectives for the Estuary; third, **determine whether** the current level of harvest could effect the ability of **the Council** to accomplish **its desired levels of** protection and restoration; and, fourth, to understand the degree to which harvest, legal **and**/or illegal, may limit **the** benefits to the fishery from management measures directed toward **solving** other problems.

Efforts to protect the winter-run Chinook salmon, delta smelt, and other depleted fishery resources have resulted in **restrictions on** to the operations of the State Water Project (SWP) and **federal** Central Valley Project (CVP). **Project constraints** have affected the ability of the Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) to **balance**

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management of water supplies for direct human use **and other uses**. Concerns have been expressed that **these** constraints on water management **have been** imposed without fully considering how other, **non-project** factors **impacting** acting in the Estuary may have severely limited or precluded the recovery of species, as well as the restoration and protection of the Estuary's ecosystem. Other **such** factors that have been **identified** include harvest by humans, entrapment **in Delta diversions**, non-native species introductions, **pollution,** ~~toxics~~ toxins and declining ocean productivity.

This paper, which examples the impact of harvest, complements information already provided to the Council on the effects of harvest in the briefing paper titled "Briefing Paper on Biological Resources of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary," particularly the section titled "Factors Controlling the Abundance of Aquatic Resources in the Sacramento-San Joaquin Estuary," dated September, 1993. In that briefing paper, the effect of human harvest was generally portrayed to be a relatively minor factor affecting the Estuary's fishery resources, when compared to the influence of water flows into the Delta, Delta outflows, and water exports. **Some biologists and water managers** strongly disagree with that conclusion and **believe fish** harvest is a major factor that needs to be **better** understood and addressed **as part of** the Council's efforts to "fix" the Delta.

Similar concerns have been raised during efforts to restore other ecosystems. For instance, efforts are **currently** underway to halt the decline and recover salmon resources in the Columbia River Basin and in other river systems from northern California, such as the Klamath River, to the Canadian border. Targeting the Columbia River Basin's dams and hydroelectric facilities and focusing on flow augmentations, has been met by some with skepticism. Alternate hypotheses have been forwarded that expand the list of causes for these declines to include other factors **such as** harvest and unscreened irrigation diversions. Severe restrictions on the ocean harvest, both sport and commercial, are being pursued as a significant component to recover some salmon stocks. This paper explores the arguments for and against similar restrictions which could be applied to restore salmon stocks here **in California**.

Divergent positions on the issue of how harvest of fish by humans has affected populations of those fish **are discussed**. Overviews of the major types of fishery harvest, the effects of the harvest on populations of seven selected fish species in the Estuary, and a brief review of current regulations in effect and enforcement efforts underway to control illegal harvest **are provided**.

This paper should not be considered an exhaustive treatment of issues related to the harvest of fishery resources in the Estuary, nor of measures to control illegal harvest. The dedicated efforts of Department of Fish and Game wardens, U.S. Fish and Wildlife agents, National Marine Fisheries Service agents, U.S. Coast Guard personnel, and others enforcing harvest regulations and reducing illegal take, are only briefly described in this report. Though our knowledge of the level of illegal take is far from definitive, there **undoubtedly exists** a need to reduce illegal take.

Sport, commercial, and illegal harvest of estuarine fishes and invertebrates varies according to population size and regulation. More restrictive regulations have been imposed when populations of fishes have declined. When populations have reached critically low levels commercial and sport closures have been imposed **in some instances.** For example, seasonal fishing closures on the Sacramento River and in the Pacific Ocean have been **instituted** to protect stocks of winter-run Chinook salmon.

Over 200 species of shrimp, crab, and fishes live in the Estuary. Nearly 100 species of fishes occupy the more brackish to marine portions of the Estuary (Table 1), while the brackish to freshwater portions offer habitat for 35 species of fishes (Table 2). Six species of anadromous fish that are targets of significant fisheries, spawn, rear in, **or pass through** the Estuary. They are white sturgeon, green sturgeon, American shad, striped bass, steelhead, and Chinook salmon. Many of the species listed are taken either commercially or by sport anglers. In some cases, such as salmon, they support both sport and commercial fishing. Many of the fish listed are vulnerable to illegal take.

Table 1. Marine and Brackish Water Fish Species that Occur in the Sacramento/San Joaquin Estuary.

Pacific lamprey	brown rockfish	C-O sole
river lamprey	yellowtail rockfish	curlfin sole
sevengill shark	black rockfish	hornyhead turbot
Thresher shark	blue rockfish	sand sole
brown smoothhound	red Irish lord	California tonguefish
leopard shark	brown Irish lord	ocean sunfish
spiny dogfish	Pacific staghorn sculpin	plainfin midshipman
Pacific electric ray	fluffy sculpin	smooth ronquil
big skate	cabezon	blue lanternfish
bat ray	bonehead sculpin	barred surfperch
Pacific herring	scalyhead sculpin	calico surfperch
Pacific sardine	tidepool sculpin	shiner perch
whitebait smelt	white croaker	black perch
surf smelt	queenfish	spotfin surfperch
longfin smelt	halfmoon	walleye surfperch
night smelt	senorita	silver surfperch
delta smelt	kelp greenling	rainbow seaperch
Pacific tomcod	lingcod	dwarf perch
Pacific hake	painted greenling	white seaperch
northern lampfish	Pacific sandlance	rubberlip seaperch
northern anchovy	rockpool blenny	pile perch
Pacific argentine	topsmelt	chameleon goby
California lizardfish	jacksmelt	blackeye goby
Pacific saury	medusafish	longjaw mudsucker
threespine stickleback	Pacific pompano	bay goby
bay pipefish	Pacific barracuda	yellowfin goby
showy snailfish	striped mullet	cheekspot goby
spotted cusk-eel	onespot fringehead	arrow goby
Pacific blacksmelt	striped kelpfish	goby type II
red brotula	monkeyface prickleback	arrow/cheekspot goby
northern clingfish	penpoint gunnel	Pacific sanddab
pygmy poacher	saddleback gunnel	speckled sanddab
chub mackerel	starry flounder	

Table 2. Resident Fish Species of the Brackish and Freshwater Portions of the Sacramento-San Joaquin Estuary.

Centrarchidae	**Cyprinidae**
*Sacramento Perch	*Sacramento Squawfish
Largemouth Bass	*Hitch
Smallmouth Bass	*Sacramento Splittail
Bluegill	*Sacramento Blackfish
Redear Sunfish	*Hardhead
Green Sunfish	Golden Shiner
Warmouth	Goldfish
Black Crappie	Carp
White Crappie	Fathead Minnow
Pumpkinseed	
Sunfish Hybrids	
Other	**Ictaluridae**
*Delta Smelt	Channel Catfish
*Sacramento Sucker	White Catfish
*Tule Perch	Brown Bullhead
*Threespine Stickleback	Black Bullhead
*Riffle Sculpin	
Prickly Sculpin	
Bigscale Logperch	
Inland Silversides	
Mosquitofish	
Threadfin Shad	
Yellowfin Goby	

*Indicates native species

CHINOOK SALMON

Four races of Chinook salmon **may be found in the Estuary**: fall-run, late fall-run, winter-run and spring-run (Fisher 1993). The fall run is the most abundant of the four runs in the Sacramento River and the only one now occurring in the San Joaquin River. Approximately 80 percent of all four runs are produced in the Sacramento River system. Currently, more than 90 percent of all spawners are fall-run fish (Chadwick and Herrgesell 1993).

Population Size

Historically, Chinook salmon stocks were **"counted" through** the use of commercial catch records. **This method** was replaced with spawning ground surveys in the 1940s. Chinook spawning ground surveys involve mark and re-capture techniques, fish ladder counts, and aerial redd surveys. Spawning ground surveys are used **only** to estimate fall-run Chinook populations (Mills and Fisher 1994).

When the Red Bluff Diversion Dam (RBDD) was completed in 1967, **its fish counting facilities** made it possible to **estimate** the number of spring-run, late fall, and winter-run Chinook salmon, as well as steelhead, in the upper Sacramento River. Direct counts **are made** at RBDD and **other** salmon and steelhead hatcheries as **the fish** ascend fishways or ladders. A variation of this direct count method involves the use of electronic fish counters that are adjusted to register the passage of an adult size fish through a tube. It should be noted that at RBDD fish are handled to differentiate and identify winter-run fish.

Mark and re-capture techniques are used to estimate Chinook fall-run populations. The Adjusted Petersen Population Estimate (Ricker 1973, see glossary) is the most common **method used** and involves a single census procedure in which salmon are marked once and their numbers are recorded during following recapture. However, like all estimates, this mark-recapture method requires assumptions be made regarding several factors: 1) survival of marked fish; 2) loss level of tag; 3) random mixing of marked fish in the population; 4) a high level of mark recognition; and, 5) a low level of recruitment of adult fish to the population during the recovery of marked fish.

Aerial redd counting is used in the Sacramento Valley, particularly between Princeton and Keswick along the Sacramento River. The redd counts below RBDD are compared to redds above the RBDD and a ratio is calculated. The number of fish spawning above RBDD is determined by direct count and those spawning below RBDD is calculated by multiplying the redd ratio by the number of spawners above RBDD (Mills and Fisher 1994).

On the Feather River, spawning stock surveys for spring-run and fall-run are conducted in the Feather River and a spawning channel adjacent to it (Moe's Ditch). Most of the spring-run salmon are believed to enter **the** Feather River Hatchery and are counted there.

On the Yuba River, spawning stock surveys are **conducted** weekly from October through December in the following river sections:

1. Highway 20 bridge to Daguerre Point Dam.
2. Daguerre Point Dam to Hallwood Avenue.
3. Hallwood Avenue to Marysville Dump.

A Schaefer model is used to make the **Yuba** population estimates. **Also** males and females are tagged differently to distinguish relative recovery rates.

On the American River, spawning stock survey trips are conducted from November through December. A Schaefer model is used to estimate the population **here as well**. The river is divided into two sections for the surveys:

1. Nimbus Racks to Rossmoor Bar
2. Rossmoor Bar to Watt Avenue Bridge

In 1993, the DFG estimated there were 29,000 ~~50,296~~ natural fall-run Chinook salmon in the Sacramento River and an additional 19,000 ~~18,615~~ hatchery fall-run Chinook salmon for a total fall-run escapement of nearly 48,000 ~~69,000~~ Chinook salmon (Table 3). ~~These estimates surpassed the natural and hatchery fall-run Chinook estimates in both 1992 (52,129) and 1991 (48,973).~~ The contribution from the Feather River has averaged 36,000 37,000 annually for the last three years, while the American River contributed an annual average of ~~16,000~~ 24,000 (Table 4). While these estimates are not divided into natural spawning stocks and hatchery stocks, the majority of the salmon were hatchery fish. The Yuba River contributed an annual average of ~~8,000~~ 9,000 for the last three years, with all being naturally spawning fish. ~~The combined contribution of 61,000 represents a decline of 38 percent from the average annual total between 1952 and 1992 of 98,000.~~

The 1992 estimate of the late fall-run population for the upper Sacramento River was 10,370, which was on a par with the 10 year average of 10,313. (F. Fisher, DFG, pers. comm.). ~~Preliminary 1993 estimates are 1,514, however, since this represents only a partial count, a final figure is not yet available.~~

The DFG estimates there were fewer than 500 spring-run Chinook salmon in the Sacramento River above Red Bluff Diversion Dam during 1992. Sacramento River spring-run Chinook salmon numbered more than 20,000 during the 1960s (Table 3) (Chadwick and Herrgesell 1993). The 1993 estimates are less than 400.

Table 3. Sacramento River Chinook Salmon Spawner Escapement Estimates 1952-1993 (*above mouth of Feather River*) and Red Bluff Diversion Dam Counts 1967-1993. Data for Chinook Salmon Population Estimates Gathered from: Fry 1960 (years 52-59), Fry and Petrovich 1970 (years 1960-1966), and Mills and Fisher 1993 (1967-1991), F. Fisher pers. comm (1992-1993).

Year	Natural Fall-Run	Natural and Hatchery Fall-Run Combined (Battle Creek)	Red Bluff Diversion Dam Counts			
			Fall run	Late -Fall	Winter-run	Spring-run
1952	298,000	15,000				
1953	435,000	16,000				
1954	298,000	12,000				
1955	238,000	26,000				
1956	102,000	21,000				
1957	77,000	5,000				
1958	140,000	29,000				
1959	273,000	30,000				
1960	261,000	24,000				
1961	173,000	20,000				
1962	171,000	13,000				
1963	180,000	17,000				
1964	172,000	16,000				
1965	117,000	9,000				
1966	131,000	3,000				
1967	99,000	5,000	89,220	37,208	57,306	23,514
1968	128,000	7,000	122,095	34,733	84,414	14,684
1969	151,000	6,000	133,815	38,752	117,808	26,505
1970	77,000	9,700	80,935	25,310	40,409	3,652
1971	86,000	6,900	63,918	16,741	43,089	5,830
1972	54,500	5,200	42,503	32,651	37,133	7,346
1973	66,000	8,800	53,891	23,010	24,079	7,762
1974	81,000	5,300	54,952	7,855	21,897	3,933
1975	96,000	5,738	63,091	19,659	23,430	10,703
1976	92,000	7,593	60,719	16,198	35,096	25,983
1977	75,000	11,000	40,444	10,602	17,214	13,730
1978	86,000	3,700	39,826	12,586	24,862	5,903
1979	121,000	13,000	62,108	10,398	2,364	2,900
1980	58,000	14,000	37,610	9,481	1,156	9,696
1981	86,000	20,000	53,744	6,807	20,041	21,025
1982	52,000	27,000	48,431	4,913	1,242	23,438
1983	67,000	14,000	42,096	15,190	1,831	3,931
1984	76,000	30,000	73,254	7,163	2,663	8,147

1985	134,000	40,000	97,707	8,436	3,962	10,747
1986	166,000	31,000	104,873	8,286	2,464	16,691
1987	12,000	24,000	103,063	16,049	1,997	11,204
1988	146,000	66,000	139,966	11,597	2,094	9,781
1989	84,000	31,000	84,057	11,639	533	5,255
1990	57,000	21,000	55,710	7,305	441	3,922
1991	39,000	17,000	44,937	7,089	191	773
1992	38,000	13,000	41,376	10,371	1,180	431
1993	29,000	19,000	56,896	No Count	341	388
Average	126,718	17,094	70,046	15,770	21,083	10,292

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Table 4. Fall-run Chinook Salmon Population Estimates for the Sacramento, Feather, Yuba, and American Rivers. Data for Chinook Salmon Population Estimates Gathered from: Fry 1960 (years 52-59), Fry and Petrovich 1970 (years 1960-1966), and Mills and Fisher 1993 (1967-1991), F. Fisher pers. comm (1992-1993).

Year	Sacramento River	Feather River	Yuba River	American River	Grand Total
1952	313,000			25,000	338,000
1953	451,000	28,000	6,000	28,000	513,000
1954	310,000	68,000	5,000	29,000	412,000
1955	264,000	86,000	2,000	17,000	369,000
1956	123,000	18,200	5,000	6,400	152,600
1957	83,000	11,000	1,000	7,700	102,700
1958	169,000	32,000	8,000	27,000	236,000
1959	303,000	76,000	10,000	31,000	420,000
1960	261,000	80,000	20,400	54,000	415,400
1961	173,000	44,000	9,200	25,500	251,700
1962	169,000	19,000	34,300	27,000	249,300
1963	179,500	33,900	37,000	41,000	291,400
1964	172,000	38,000	35,000	59,000	304,000
1965	118,000	23,000	10,200	39,000	190,200
1966	132,000	21,000	7,800	27,000	187,800
1967	87,300	12,000	23,500	23,000	145,800
1968	107,400	18,000	7,000	31,000	163,400
1969	132,200	61,000	6,000	47,000	246,200
1970	71,800	58,000	14,000	29,000	172,800
1971	80,200	43,500	6,000	42,000	171,700
1972	51,000	43,000	9,000	17,400	120,400
1973	60,400	65,100	24,000	82,000	231,500
1974	76,000	59,300	18,000	54,000	207,300
1975	90,000	37,735	6,000	32,000	165,735
1976	83,000	59,000	38,000	23,000	203,000
1977	65,000	38,000	9,000	42,000	154,000
1978	82,000	33,000	7,400	13,000	135,400
1979	115,000	28,415	12,400	37,000	192,815
1980	52,400	32,000	12,400	34,000	130,800
1981	69,000	45,000	14,000	43,000	171,000
1982	42,000	48,000	39,000	33,000	162,000
1983	58,000	23,000	14,000	26,400	121,400
1984	56,000	41,500	10,000	27,000	134,500
1985	103,000	50,000	13,000	56,000	222,000

1986	102,000	47,000	19,400	49,000	217,400
1987	*109,000*	59,000	18,500	21,000	207,500
1988	86,000	54,000	8,500	16,000	164,500
1989	59,000	30,000	10,000	17,000	116,000
1990	50,000	25,000	4,000	6,700	85,700
1991	29,000	27,802	14,000	18,000	88,802
1992	52,000	40,500	6,000	10,600	109,100
1993	69,000	41,000	6,000	45,000	161,000
Average	117,743	40,413	13,512	31,066	210,354

The 1993 estimate of winter-run Chinook salmon in the Sacramento River was 341, down from 1,180 salmon in 1992. Winter-run Chinook salmon were at record low numbers in 1991, with just 191 ~~**estimated**~~ **adults counted at the** ~~from counts at the~~ Red Bluff Diversion Dam. Spawning numbers for winter-run Chinook salmon, which **has been** listed as endangered under both the Federal and State endangered species acts, are expected to remain at low levels (below 5,000) (Gary Sterns, NMFS pers. comm.) for the next several years (5 to 10 years) because of a greatly reduced population and declining recruitment. ~~(Table 3) (Chadwick and Herrgesell 1993).~~

The 1992 population estimate for fall-run Chinook salmon in the San Joaquin River was over 4,700 fish. Of those, approximately 3,700 (~~79~~ 78 percent), were **natural** stocks and the other 1,000 **or so** were hatchery salmon. The estimate for Chinook salmon in the San Joaquin River for the last 10 years **has** averaged nearly 31,000 annually (Table 5) ~~(F. Fisher, DFG, pers. comm.).~~

The reader is referred to the BDOC briefing paper on Biological Resources for further details on populations of Estuary fisheries.

Types of Harvest

The commercial harvest of salmon in California is accomplished by deep water trolling vessels. Trolling involves towing lures or bait through the water on a line attached to a heavy lead ball (Browning 1974, Crutchfield and Pontecorvo 1969). Sport harvest in the ocean in small private boats or larger party boats is conducted by anglers with fishing rods and reels drifting or trolling with bait or lures (von Brant 1972).

Salmon are caught in the Sacramento-San Joaquin Estuary and the Sacramento River by sport anglers using rod and reel from shore and from small private boats. Lures and bait are trolled or fished on the river bottom.

Table 5. San Joaquin River System Chinook Salmon Population Estimates for Natural and Hatchery Stocks 1952-1992. Data for Chinook Salmon Population Estimates and Hatchery Returns Gathered from: Fry and Petrovich 1970 (years 1960-1966) and F. Fisher (DFG Biologist) (pers. comm.) (1967-1991).

Year	Natural Area Fall-Run	Hatchery Fall-Run	Total System
1952	22,000	0	22,000
1953	84,000	0	84,000
1954	75,000	0	75,000
1955	31,000	0	31,000
1956	12,500	0	12,500
1957	15,000	0	15,000
1958	46,000	0	46,000
1959	52,000	0	52,000
1960	56,000	0	56,000
1961	2,700	0	2,700
1962	2,000	0	2,000
1963	1,800	0	1,800
1964	10,200	362	10,562
1965	7,100	173	7,273
1966	9,400	480	9,880
1967	24,000	250	24,250
1968	19,000	954	19,954
1969	51,000	615	51,615
1970	37,000	1,008	38,008
1971	41,600	1,430	43,030
1972	14,300	473	14,773
1973	7,100	783	7,883
1974	4,400	1,220	5,620
1975	6,700	1,099	7,799
1976	3,900	774	4,674
1977	1,300	0	1,300
1978	2,600	584	3,184
1979	9,000	734	9,734
1980	6,300	796	7,096
1981	28,300	2,310	30,610
1982	16,900	2,866	19,766
1983	60,200	6,368	66,568
1984	56,000	2,844	58,844
1985	76,200	1,434	77,634
1986	21,700	2,563	24,263

1987	25,000	1,588	26,588
1988	21,900	585	22,485
1989	3,800	162	3,962
1990	1,200	117	1,317
1991	854	185	1,039
1992	3,668	1,062	4,730
Average	23,674	1,166*	24,499

*Average based on 29 years of data from 1964-1992

Methods of illegal salmon take include gillnetting, longlining, snagging, exceeding bag limits, and keeping fish shorter than the legal length. Gillnets are fished by stretching a fine mesh net in the river across a channel or inlet. Longlining involves the attachment of many hooks to a central line which is often attached to the river bank (California Sport Fishing Regulations 1994). Snagging involves hooking fish in the body rather than the mouth usually by dragging large, multipoint hooks through schools of fish (von Brant 1972).

Illegal Harvest

Illegal harvest of Chinook salmon in the Estuary **has been** estimated to result in a **potential** loss of spawning stock that **may** have produced 250,000 **additional** salmon smolts annually (We're Saving Fish, DFG 1994). This loss of young salmon represents the estimated production of 500 adult female salmon (F. Fisher, DFG pers. comm.). This **estimated smolt loss** was calculated by biologists using the typical number of eggs produced by a single female (approximately 5,000/female), the rate of survival of those eggs to the fry stage (approximately 20%), and the rate survival to the smolt stage (approximately 50%). This estimate was also based, in part, on previously **gathered** data on citations written and **the** number of illegally caught salmon seized by DFG wildlife protection staff. These data were then converted into estimates of total illegal take by estimating the interdiction rate. DFG wildlife protection staff estimate that they interdict approximately two percent of the total number of illegal anglers.

Salmon **of sub-legal size** are generally not **harvested because they** leave the river at approximately 4 inches in length and are not encountered in the ocean fishery, legally or illegally, until they have reached a length of 16-18 inches (A. Baracco, DFG, pers. comm.).

Recently, considerable attention has been focused on the **possible** effects of **concentrated** over fishing by foreign trawlers off of the Pacific Coast. However, while concerns about the high seas drift net fishery are well founded for species such as cod, flounder, and potentially Alaskan and British Columbia salmon stocks (such as sockeye, chum, and pink), there is no evidence that the Central Valley salmon fishery is **similarly** impacted (A. Baracco, DFG, pers. comm.).

Foreign fishery vessels are not allowed to fish for federally managed species, such as Chinook salmon, **with**in the 200 mile Exclusive Economic Zone. National Marine Fisheries Service, Coast Guard and DFG patrols using sophisticated radar and other detection and enforcement techniques, help ensure compliance from near shore areas out to 200 miles. Central Valley salmon are not found beyond 200 miles from the California coast, a**nd are thus not subject to foreign harvest pressures.**

Sport Fishing Harvest

The annual sport catch **data for** Chinook salmon in the mainstem **of the** Sacramento River for **the** years 1967 through 1991 is shown in Table 6. Harvest numbers for the San Joaquin **River** and its tributaries are not available **because of** upstream of the very low number of fish returning to spawn and the generally zero possession limit in its tributaries and the Delta (F. Fisher, DFG, pers. comm.).

The annual **estimated sport** harvest of fall-run Chinook salmon in the mainstem Sacramento River for 1991 was 10,075 fish, well above the previous twenty-four year average of approximately 7,500 fish from 1967 to 1990. Harvest was equal to or above previous levels, excluding 1975-76, 1985-86 and 1988 when the catch averaged **about** 16,000 fish (F. Fisher, DFG, pers. comm.). The high harvest in those years can be attributed to an increase in the abundance of adult salmon returning to the Sacramento River and its tributaries to spawn ~~(Table 4).~~

The **estimated** late fall-run Chinook salmon **sport** harvest in 1991 was 531 fish, a decline of roughly 50 percent **from** the average of approximately 1,000 from 1967 through 1991. The **sport** harvest, which averaged about 1,500 fish from 1967 to 1977, declined steadily after that with the exception of 1986 when ~~population grew to~~ the sport harvest was over 2,300 fish (F. Fisher, DFG, pers. comm.).

Table 6. Annual Chinook Salmon Sport Harvest in the Sacramento River (Mills and Fisher 1993 (1967-1991)).

Year	Late Fall-Run	Winter-Run	Spring-Run	Fall-Run	Total
1967	2,504	3,602	1,885	4,267	12,258
1968	2,047	11,308	802	4,471	18,628
1969	1,433	9,095	1,659	7,563	19,750
1970	748	4,440	762	7,889	13,839
1971	1,165	6,735	400	9,477	17,778
1972	2,658	2,962	696	5,987	12,303
1973	2,599	2,944	1,149	6,465	13,157
1974	567	1,541	321	6,727	9,156
1975	1,190	2,014	1,047	10,632	14,883
1976	921	4,268	2,145	11,047	18,381
1977	1,058	1,667	830	4,889	8,443
1978	528	910	538	4,839	6,816
1979	477	107	151	7,438	8,173
1980	460	55	803	4,853	6,172
1981	335	961	1,185	3,699	6,179
1982	162	50	1,115	4,578	5,905
1983	593	59	234	4,247	5,133
1984	241	78	745	6,087	7,150
1985	430	548	1,171	16,533	18,682
1986	2,340	138	1,846	15,340	19,665
1987	943	89	688	9,630	11,350
1988	680	0	600	11,488	12,768
1989	685	0	322	6,850	7,856
1990	330	0	215	5,290	5,835
1991	531	0	57	10,075	10,663
Average	1,025	2,143	855	7,615	11,637

The spring-run Chinook salmon **sport** harvest, which as recently as 1986 numbered more than 1,800 fish, declined to **only** 57 fish in 1991 ~~(F. Fisher, DFG, pers. comm.)~~ (Table 6).

Sacramento River winter-run Chinook salmon sport harvest records show that 1968-69 were the peak harvest years averaging ~~**about**~~ 10,200 fish. After 1969, harvest of the winter-run population began an uneven decline to just 89 fish by 1987. The sport fish harvest rate of winter-run salmon in 1989 was 4 percent of the total population estimate for that year, however, from 1967-1986 the winter-run harvest rate averaged 8 percent of the population. Harvest rates for winter-run salmon ranged from a high 16 in 1971 to low of 3 in 1985 and 1986. In August, 1989, the State of California listed the winter-run as endangered. The National Marine Fisheries Service (NMFS), listed it as threatened in November, 1990~~(Table 6) (F. Fisher, DFG, pers. comm.).~~ It **has** now **also been** listed as endangered by NMFS.

The sport harvest (recreational) of Chinook salmon ~~**landed**~~ **caught off shore** in the Pacific Ocean and landed at docks in San Francisco and Monterey bays fluctuates widely. Available sport harvest records cover the years 1967 through 1991. Estimated numbers of fish caught have declined unevenly from a high of approximately ~~176,500~~ 187,000 fish in 1972 to a record low of approximately ~~37,000~~ 53,000 in ~~1991~~ 1983 (Table 7) ~~(Mills and Fisher 1994).~~

Commercial Fishing

Commercial harvest of Central Valley Chinook salmon ~~by trollers~~ in the Pacific Ocean, is landed at ports surrounding San Francisco and Monterey bays and averaged approximately ~~218,000~~ 150,337 fish annually from 1967 through 1991. Commercial harvest in the last five years of that period ranged from a high of over ~~642,000~~ 830,511 salmon in 1988 to nearly ~~174,000~~ 254,629 salmon in 1991 (Table 7). From 1967 through 1972 combined Chinook salmon landings from San Francisco and Monterey averaged approximately ~~149,000~~ 200,163 salmon annually. During the period, 1986 through 1991, commercial harvest increased to an average of **approximately** ~~322,000~~ 455,739 salmon annually.

~~Table 7. Chinook Salmon Sport and Commercial Harvest (numbers of fish) Sacramento River-Pacific Ocean 1967-1991.~~

~~Year~~	~~Sacramento River Harvest*~~	~~Ocean Harvest Landed in San Francisco Bay~~		~~Total~~
		~~Commercial~~	~~Recreational~~	
~~1967~~	~~12,258~~	~~69,533~~	~~58,503~~	~~140,294~~
~~1968~~	~~18,628~~	~~167,953~~	~~123,807~~	~~310,388~~
~~1969~~	~~19,750~~	~~176,749~~	~~113,517~~	~~310,016~~
~~1970~~	~~13,839~~	~~163,097~~	~~97,300~~	~~274,236~~
~~1971~~	~~17,778~~	~~125,755~~	~~145,879~~	~~289,412~~
~~1972~~	~~12,303~~	~~189,558~~	~~176,503~~	~~378,364~~
~~1973~~	~~13,157~~	~~242,412~~	~~167,017~~	~~422,586~~
~~1974~~	~~9,156~~	~~222,785~~	~~130,242~~	~~362,183~~
~~1975~~	~~14,883~~	~~160,434~~	~~84,977~~	~~260,294~~
~~1976~~	~~18,381~~	~~138,231~~	~~63,760~~	~~220,372~~
~~1977~~	~~8,443~~	~~185,164~~	~~72,595~~	~~266,202~~
~~1978~~	~~6,816~~	~~158,158~~	~~64,085~~	~~229,059~~
~~1979~~	~~8,173~~	~~180,087~~	~~102,547~~	~~290,807~~
~~1980~~	~~6,172~~	~~211,778~~	~~73,093~~	~~291,043~~
~~1981~~	~~6,179~~	~~199,910~~	~~70,084~~	~~276,173~~
~~1982~~	~~5,905~~	~~281,761~~	~~116,910~~	~~404,576~~
~~1983~~	~~5,133~~	~~75,019~~	~~49,717~~	~~129,869~~
~~1984~~	~~7,150~~	~~167,668~~	~~73,233~~	~~248,051~~
~~1985~~	~~18,682~~	~~175,681~~	~~112,475~~	~~306,838~~
~~1986~~	~~19,665~~	~~302,302~~	~~86,255~~	~~408,222~~
~~1987~~	~~11,350~~	~~355,615~~	~~119,526~~	~~486,491~~
~~1988~~	~~12,768~~	~~642,693~~	~~114,455~~	~~769,916~~
~~1989~~	~~7,856~~	~~255,817~~	~~93,659~~	~~357,332~~

~~1990~~	~~5,835~~	~~199,147~~	~~77,562~~	~~282,544~~
~~1991~~	~~10,663~~	~~174,831~~	~~37,274~~	~~222,768~~
~~Average~~	~~12,122~~	~~217,589~~	~~101,041~~	~~330,752~~

~~*Sport harvest only, no commercial harvest allowed on the Sacramento River.~~

Table 7. Commercial and Recreational Harvest (numbers of fish) of Chinook Salmon In Monterey and San Francisco bays and Sacramento River 1967-1991. Mills and Fisher 1994 (3rd Draft).

Year	Sacramento River Harvest	Ocean Harvest Landed in San Francisco Bay		Ocean Harvest Landed in Monterey Bay		Total
		Commercial	Recreational	Commercial	Recreational	
1967	12,258	69,533	58,503	17,549	7,650	165,493
1968	18,628	167,953	123,807	58,255	25,095	393,738
1969	19,750	176,749	113,517	103,613	14,737	428,366
1970	13,839	163,097	97,300	63,732	13,838	351,806
1971	17,778	125,755	145,879	24,944	20,448	334,804
1972	12,303	189,558	176,503	40,238	11,089	429,691
1973	13,157	242,412	167,017	180,283	13,886	616,755
1974	9,156	222,785	130,242	59,895	11,348	433,426
1975	14,883	160,434	84,977	73,927	7,717	341,938
1976	18,381	138,231	63,760	99,626	4,807	324,805
1977	8,443	185,164	72,595	78,675	4,006	348,883
1978	6,816	158,158	64,085	132,842	1,809	363,710
1979	8,173	180,087	102,547	54,060	5,929	350,796
1980	6,172	211,778	73,093	82,524	4,020	377,587
1981	6,179	199,910	70,084	89,995	3,743	369,911
1982	5,905	281,761	116,910	136,678	5,586	546,840
1983	5,133	75,019	49,717	103,215	3,243	236,327
1984	7,150	167,668	73,233	53,992	5,437	307,480
1985	18,682	175,681	112,475	36,637	9,276	352,751
1986	19,665	302,302	86,255	200,154	28,558	636,934
1987	11,350	355,615	119,526	91,231	33,320	611,042
1988	12,768	642,693	114,455	187,818	15,919	973,653
1989	7,856	255,817	93,659	107,955	37,248	502,535
1990	5,835	199,147	77,562	137,072	35,053	454,669
1991	10,663	174,831	37,274	79,798	24,830	327,396
Average	11,637	208,886	96,999	91,788	13,944	423,254

Even though declines are occurring in the natural populations of salmon, hatchery production techniques are picking up the slack and are increasing the populations of fall-run salmon in the Sacramento River tributaries such as the American and Feather Rivers and Battle Creek. Hatchery operations tied together with improved environmental conditions in the ocean and rivers has led to the increase in the average salmon harvest from 1986 through 1991.

Though hatchery production has been used to augment decreasing natural stocks available for commercial harvest, and commercial fishermen do indeed rely on them for much of their livelihood, there is significant concern among commercial fishermen and resource managers regarding the increasing dominance of hatchery production as opposed to restoration of natural stocks. "Natural" fish are considered to be critical to preserving a native gene pool which, in turn, contribute to the long-term vitality and viability of the naturally produced species. Of particular concern to the commercial industry, as well, is the apparent excessive reliance upon artificial hatchery production as a perceived panacea by other interests and in particular the regulatory community. Fishing interests argue that concentrated efforts should instead be focused on protecting and creating healthy instream habitat. Hatcheries should be supplemental to, not supplant natural production, as the latter provides the best long-term, reliable foundation for a sustainable fishery. Finally, while hatchery production is some times touted in other circles as a boon, commercial fishing interests believe it should be emphasized that such efforts were initiated and are continued as a consequence of failures to sufficiently protect natural populations and their habitat. Ultimately, the goal should be to work toward balancing hatchery production with robust **natural** stream production (W. Kier, pers. comm.).

Other **types of commercial fisheries contribute to the problem of** incidental salmon take. For example, to harvest Pacific whiting, commercial fishermen use mid water- trawls that are about the size of a football field. Nevertheless, the incidental take is very low, with an estimated 5,000 salmon taken from California to Washington annually. The number of salmon originating from the Sacramento or San Joaquin river systems represents only a **very small** fraction of that total.

Effect of Harvest on Populations

In order to establish the context **for investigating** the effect of harvest on salmon populations, it is important to note that observed changes in adult salmon populations **reflect the** interrelationship between harvest and **alterations in** productivity.

When major declines in fish stocks occur as a result of habitat degradation, restrictions in harvest can slow, but not prevent, a decline in abundance. Winter-run Chinook salmon are an excellent example of this principle.

For instance, the recent serious decline in the population of the winter-run Chinook salmon **has been** principally **attributable to** under-production due to spawning habitat degradation, predation, entrainment in water diversions, and disruption of fish migration routes. Although harvest rates remained relatively stable or **were** significantly decreased **through regulatory efforts**, the winter-run population **still** continued to decline **because of** declining recruitment. Under conditions of significantly decreasing productivity, which can occur as a result of declining quality of spawning habitat predation, entrainment and other general environmental conditions, reducing or eliminating harvest normally has the effect of slowing the rate of decline **but not halting it.** (A. Baracco, DFG, pers. comm.). Nevertheless, harvest and its control are important components of management for salmon stocks **along the Pacific Coast and** in the Sacramento River and San Joaquin River basins. When non-fishing mortality is reduced and productivity is increased through management measures, **fishing** controls can **also contribute to** the recovery of salmon populations.

The Pacific Fishery Management Council (PFMC) has set an annual spawning escapement **goal** for Sacramento fall-run Chinook salmon of between 122,000 and 180,000 adult fish (PFMC 1994). This is considered the optimum spawning level for the habitat in the **Sacramento** basin, including both spawning in hatcheries and in the natural environment.

An important element in evaluating available harvestable fish and the level of **spawning** escapement required to sustain a **healthy** population or provide for its increase is the development of a recruitment curve (Appendix B).

Since escapement goals **were** not achieved during **1992 and 1993**, biologists recommended additional reductions in the ocean harvest . **Restrictions were imposed in 1994 to protect Klamath River stocks. DWR officials have stated that they will meet their escapement goals for the Fall of 1994 (R. Brown, DWR, pers. comm.).**

Undersized salmon, **taken either** by sport anglers or **inadvertently harvested by** commercial fishermen, generally can be returned successfully to the water with little mortality and **such occurrences** do not add measurably to the harvest rate. The PFMC has estimated recreational fishing mortality to be 13 percent and mortality associated with commercial fishing at 31 percent. While these mortality rates may be high, what must be considered is the rate of contact between recreational and commerical anglers and sub-legal fish. For commerical anglers, the May through July fishing period provides low contact with sub-legal fish. In addition, the mortality associated with commerical fishing is a composite of all types of losses that may occur before the fish is landed in the vessel, such as, losses to marine mammals (A. Baracco, DFG, pers. comm.).

Concerns have been raised about the accuracy of claims that salmon populations are declining in the Central Valley. These concerns are based on commercial and sport harvest data which, on their face, seem to argue against decline. Table 7 ~~**(page 17)**~~ shows that from 1967 through 1972 the average annual total harvest **of salmon** was **about** ~~284,000~~ 335,000 fish, while in more recent years (1986 through 1991) the data show that the average annual total harvest was **approximately** ~~421,000~~ 573,000 fish, a ~~48~~ 42 percent increase. This information **indicates** either 1) claims **of** declines in **salmon** populations are not accurate, or, 2) salmon populations **may now be suffering from** over-harvest.

Staff of the PFMC believe that neither of these statements correctly characterize the resource issue for reasons discussed in the remainder of this section.

Chinook Salmon Run Harvest Pattern

In order to correctly interpret the harvest numbers, the reader needs to consider the specific run being analyzed. Harvest numbers primarily reflect the harvest of fall-run salmon. While runs other than fall-run contributed an average of 57 percent of the sport harvest from 1967 through 1972, these non fall-runs only contributed an average of 12 percent for the years 1986 through 1991. The relative contribution of the various runs and the change in harvest pattern since the late 1960s and early 1970s is shown in Table 6 ~~(page 15)~~.

From the perspective of the commercial fishing industry, hatchery production is viewed as only a partial fix, necessitated by past failures to fully protect the resource and cannot be considered a replacement for healthy instream habitat. Also, previous abundance levels are not being achieved, even with intensive hatchery production. So, while hatcheries produce additional fish available for harvest, the number of salmon is far from the number necessary to satisfy the historic commercial fleet's needs if they are to be economically successful (W. Kier, pers. comm.).

Escapement/Harvest Ratio

The contention that salmon are not being over harvested is supported by the **fact that** the increase in the salmon **harvest** was **facilitated** by ideal environmental conditions in the ocean and river spawning habitat. Although the salmon harvest **figures indicate** that over-harvest of Central Valley salmon populations **may be** occurring, the ratio of salmon harvested to escapement **rates has** remained **essentially** constant (FIGURE 1). The graph shows that the ratio of harvest to spawner escapement has remained fairly constant over the 25 year period. However, since 1987 the ratio has consistently been above 2. This could be due to several factors such as, improved fishing techniques and factors related to the drought conditions that

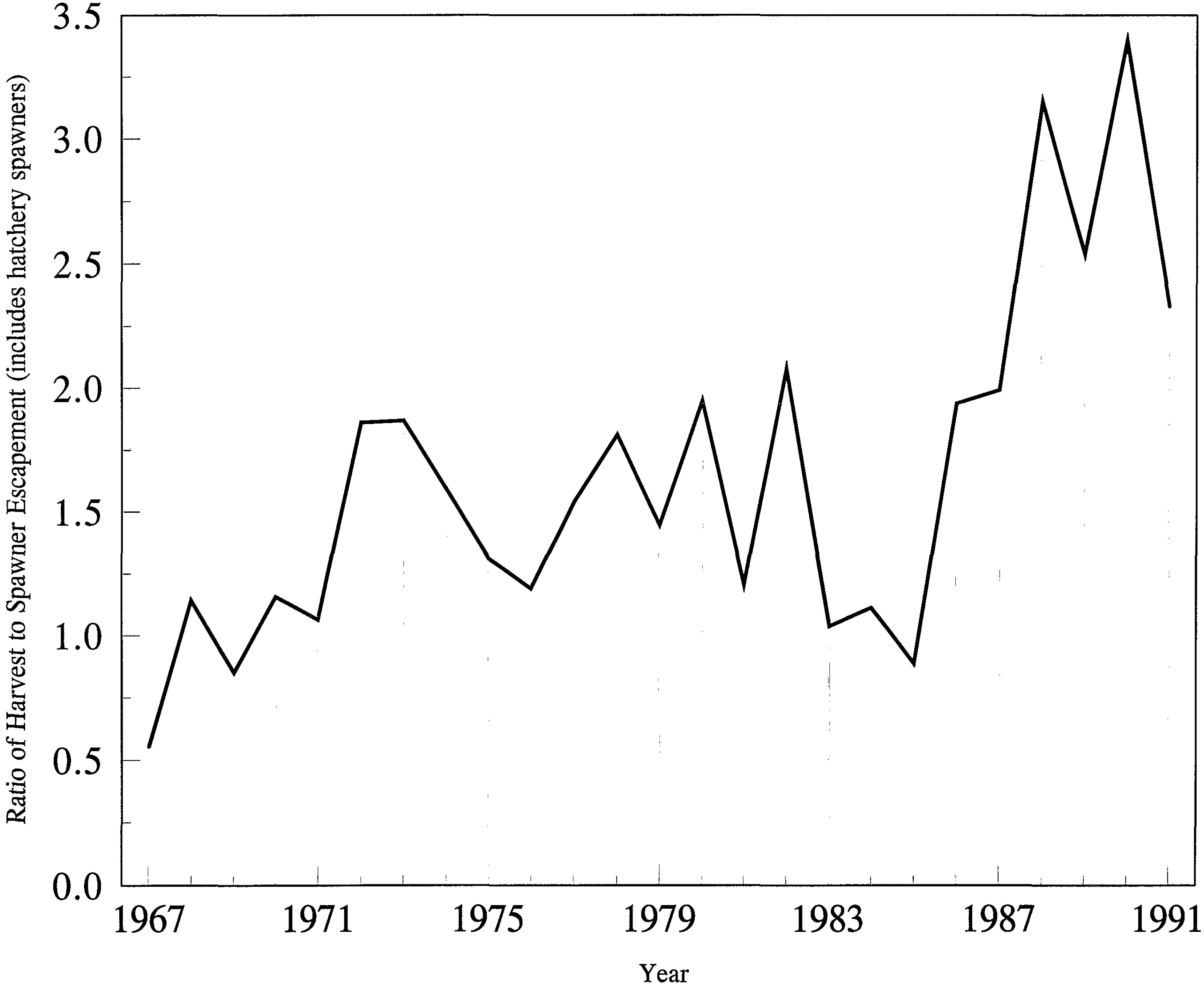

Figure 1. Ratio of salmon harvest to salmon spawner escapement (includes hatchery spawners) in the Central Valley for a 25 year history (1967- 1991). Based on Data from Mills and Fisher 1994.

occurred during this period. Additionally the number of commercial salmon fishing operations has decreased in recent years (A. Baracco, DFG pers. comm.), inferring higher probabilities of escapement **and militating against the over harvesting argument.**

Considering all **pertinen**t factors, commercial and sport fishing regulations are structured by the PFMC with the goal of **ensuring** an adequate number of spawning fish will escape **harvest** to spawn and replenish the population. However, the inability to accurately predict ocean salmon population levels results in fishing limits being set based on predicted levels, which could result in lower spawner escapement numbers (Pat Brandes, U.S. Fish and Wildlife Service, pers. comm.). The recruitment curve is not thought to be significantly lowered by the impact of **harvest** because fishing regulations are structured so that an adequate number of eggs are produced by these spawning fish to **sustain** the population in the absence of harmful environmental conditions, which can reduce the number of fish that survive to adult size. The reduction in recruitment **attribute to** environmental **degradation (such as alteration of the habitat through project operations** is thought by the PFMC to outweigh the impacts from harvest **or the reproductive capability of the fishery.**

For the above reasons, PFMC biologists believe that the current ocean harvest rates of Chinook salmon have not significantly reduced total population levels (adults). Commercial fishermen would generally agree with this conclusion, ascribing measured decreases in populations to other factors. A recent PFMC review found no evidence that Sacramento fall-run Chinook salmon -- the mainstay of the ocean fishery -- are being over harvested (W. Kier, pers. comm.).

Some water resource managers, however, point out that while water exporters are being limited to a 1% "take" of the **estimated** winter-run population at **project** diversion facilities **to comply with** ESA restrictions, the ocean harvest of winter-run **salmon** is not subject to the same level of scrutiny.

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With regard to the **mandated** 1% "take" limit, some commercial fishing interests question the validity of that figure. They believe the percentage **taken** to be larger, especially if mortality within the interior Delta is factored into the calculation rather than solely **utilizing** the estimates of losses in Clifton Court Forebay and **entrainment at** the **SWP** and CVP intakes. Also, considering the **regulatory** actions of the PFMC, claims that ocean harvest is not scrutinized and **contentions** commercial fishing is **over harvesting the** resource are without merit **in the eyes of the commercial fishing industry**. (W. Kier, per. comm.)

Ocean Harvest

The ocean harvest of winter and spring-run Chinook salmon is not thought to be a major factor in the **observed** decline of these runs because of the timing of their spawning migrations and their size during the spawning migration. Winter and spring-run Chinook salmon leave the ocean when they are two or three years old. Two year old fish have not reached commercial size and three year old fish **generally** reach this point **only** late in the commercial season, resulting in **a lower probability of** harvest. (F. Fisher, DFG, pers. comm.). However, some portion are harvested and the percentage of the population that is harvested commercially is not known. The National Marine Fisheries Service has developed an implemented a biological opinion that established ocean harvest limits that will not preclude recovery of the winter-run salmon.

Ocean fishing sport harvest regulations have also been designed to reduce catch by shortening seasons and closing certain areas to fishing. **Still,** sub-legal winter-run are ~~killed~~ **caught as a result of** incidental **sport** hooking and some mortality does occur.

Mortality of any kind for adult winter-run salmon, as with any species that has a low funcundity rate, would have an effect on the population, especially when the spawning population is already reduced.

While, in theory, **sub-legal** fish taken by commercial fishing **boats** would be returned to the ocean, the full impact **of such incidental take and catch and release** on winter and spring-run Chinook is not fully understood.

Sacramento River Harvest

Sport fishing regulations were adopted in 1987 to protect winter-run salmon in the Sacramento River, above Red Bluff Diversion Dam (DFG 1989) from **sport** angler-induced mortalities. As a result, **the annual take of sport anglers was** less than four percent of the spawning stock in 1987, 1988, and 1989. Additional **sport fishing** restrictions were adopted **to further protect** the winter-run **after it** was listed by the State as endangered in 1989. Currently, sport harvest regulations prohibit salmon fishing from January through July, when winter-run are in the Sacramento River.

Fishery Conservation and Management Act

Pursuant to the Magnuson Fishery Conservation and Management Act, the Pacific Fishery Management Council manages the level of legal **commercial** take to ensure over fishing does not occur. In 1994, the PFMC, through the Department of Commerce, prohibited commercial Coho **salmon** fishing in the coastal waters **of the Pacific northwest in response** to extremely low numbers of those fish. Along most of the coast of California, **Coho are taken only incidentally as** Chinook salmon is the primary species harvested.

Department of Commerce Regulations

Department of Commerce regulations, also **incorporated** in regulations adopted by the California Fish and Game Commission, set severe restrictions **on** the 1994 commercial ocean salmon **catch. The limit was imposed primarily as a method of achieving** increased escapement into the Klamath River system. **To counter the economic impacts caused by these** restrictions, Governor Wilson declared a state of economics emergency in Sonoma, Mendocino, Humboldt, and Del Norte counties.

Efforts to Control Illegal Harvest

To help reduce illegal harvest **of salmon, and other fishes,** in the Sacramento-San Joaquin Delta, the Delta-Bay Enhanced Enforcement Project (DBEEP) began operation in 1993. Ten wardens were hired by the DFG and equipped with four patrol boats utilizing state-of-the-art radar, navigation systems, and night scopes. The project is jointly sponsored by DWR and **the U.S. Bureau of Reclamation (USBR)**. In 1993, its first year of operation, DBEEP **estimated it prevented the loss of** 250,000 salmon smolts (We're Saving Fish, DFG Pamphlet, 1994). The DFG also limits take by restricting sport and commercial fishing in the ocean and sport fishing in the Estuary and rivers through size, season, and geographic regulations.

STRIPED BASS

Striped bass were introduced to the Estuary in 1879. By 1889 there was a thriving commercial fishery supplying San Francisco fish markets. In 1900 the **annual** commercial harvest exceeded a million pounds. The commercial striped bass fishery **was** ended in 1935 **in order** to protect **and sustain** the **burgeoning** sport fishery from over harvest (Chadwick and Herrgesell 1993).

Since the mid-1960s, the striped bass population has gradually declined. Striped bass research efforts have focused on factors affecting survival of young bass during the first year, accurate measurement of adult population size, and annual recruitment. From 1969 to 1991 the DFG tagged striped bass during their spawning migration. Following this **tagging** effort a creel census in the San Francisco Bay area **was conducted** to **measure** how many of the tagged fish **were taken by sport** anglers. The tagging and creel census projects **indicated overall** low annual recruitment of new fish, **resulting in** fewer adults which, **in turn**, results in fewer eggs spawned each year (Stevens et al. 1985, Kohlhorst, et al. 1991).

The reader is referred to the BDOC briefing paper on Biological Resources for further details on populations of Estuary fisheries.

Population Size

Adult striped bass abundance has been estimated using tag-recapture **methodology** since 1969: modified Petersen estimator (N=M (C+1)/(R+1) is used -- where N=bass abundance, M= Number of tagged fish released, C = number of fish examined for tags and R= number of tagged fish in the recapture sample.

The DFG uses gill nets and fyke net traps to capture striped bass during their spawning migration **in** the Delta and Sacramento River. These striped bass are tagged with numbered disc-dangler tags and released. The population is sampled during a year-round census of angler catches and during the following year's tagging process in the spring.

The 1969-1992 population estimates of adult, legal sized striped bass abundance **in** the Estuary **have** declined **steadily** from a high of **over** 1.8 million fish in 1975 to a 1992 total of **624,168** (Table 8) ~~(D. Kohlhorst, DFG, pers. comm.)~~. In addition to these mature fish, the 1992 population also consisted of an estimated 2,400,000 sub-adults, yearlings and two year old fish.

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Table 8. Population Estimates of Legal Size Striped Bass in the Sacramento-San Joaquin System.

Year	Total Number Legal Size Striped Bass
1969	1,646,026
1970	1,727,395
1971	1,599,716
1972	1,882,907
1973	1,637,159
1974	1,477,213
1975	1,849,771
1976	1,581,077
1977	924,301
1978	1,151,643
1979	1,155,701
1980	1,115,999
1981	911,300
1982	825,126
1983	1,009,748
1984	1,048,244
1985	1,038,126
1986	1,064,142
1987	1,037,617
1988	967,290
1989	873,065
1990	662,942
1991	799,913
1992	624,168
Average	1,243,939

Types of Harvest

Sport angling for striped bass in the Estuary consists of fishing with a rod and reel on a party boat, private boat, or from shore. Fishing in the Delta and in the Sacramento River is typically most successful during the April/May spawning migration.

Illegal Harvest of Bass

Illegal harvest occurs when anglers take more than the 2 fish limit, when anglers take striped bass shorter than the minimum size limit of 18 inches, and when they use illegal fishing methods, such as gillnetting and longlining.

To reduce poaching, the DFG, utilizing funding from DWR, initiated an enhanced law enforcement program known as Delta Bay Enhancement Enforcement Project (DBEEP).

Prior to the inception of DBEEP, DFG estimated that approximately 500,000 sub-legal striped bass were taken annually, assuming a two percent interdiction rate. If this estimate is correct, illegal take could represent 20 percent of the population of sub-legal striped bass one year of age and older. In 1993, DBEEP seized 7,038 sub-legal striped bass, of which 100 were seized from gillnetters and released (J. Gonzalez, DFG, pers. comm.). Using the same two percent interdiction rate, an illegal take of approximately 350,000 striped bass was estimated.

During the first year of the DBEEP program there was a five-fold increase in citations. Citations have declined steadily since then, which indicated a probable decrease in illegal take.

Poaching of sub-legal size striped bass was clearly at a level sufficient to decrease long term adult abundance when DBEEP began. Unfortunately, historical trend data are not available to estimate changes in illegal take over time. Consequently, the contribution of poaching sub-legal bass to the overall decline in abundance cannot be determined.

Estimates of the magnitude of the illegal catch of legal-sized striped bass are also not available. While some poaching with illegal nets occurs, and is also a target of the DBEEP program, it almost certainly represents only a very small fraction of the legal catch. Changes in poaching during the last 25 years would be included as part of the 25% of the bass decline attributed to increased adult mortality, as discussed in the next section.

Striped bass are not considered vulnerable to harvest by foreign fishing vessels because most do not venture into international fishing grounds off California's coast (D. Kohlhorst, DFG. pers. comm.)

Sport Fishing Harvest

Since 1969, an average of ~~216,800~~ 281,000 legal size striped bass have been harvested annually by sport anglers. In an effort to further protect declining populations, restrictions to reduce daily maximum catch per angler from 3 fish to 2 and to increase the legal length from 16" to 18" were introduced in 1982 (Stevens et al. 1985). The 1991 harvest estimate for striped bass in the Sacramento-San Joaquin Delta was approximately 108,000 fish which was a decline from the most recent 10-year average of ~~154,000~~ 153,000 fish (Table 9) ~~(D. Kohlhorst, DFG, pers. comm.)~~.

Effect on Population

DFG biologists have concluded that about 75 percent of the decline in adult striped bass abundance results from fewer fish reaching legal size. The other 25% of the decline is caused by increased mortality of adult bass. Among the possible causes of the other 25 percent of the decline are predation, sport fishing, pollution, and poaching. The percentage of the adult bass population legally harvested by anglers has remained steady (Table 9) which lends credence to the interpretation that legal sport fishing is not responsible for the increased mortality. There has not yet been an estimate of the contribution of other factors to the observed decline.

Historical Perspective

The relative, current influence of legal take on the observed decline in striped bass abundance can best be assessed by exploring the historic response to concerns of over-harvest.

In the late 1970s and early 1980s concerns were raised that the striped bass population reproducing in the Estuary and its tributaries had declined substantially since 1976. From 1969 to 1976 there had been about 1.7 million legal-sized striped bass (at least 16 inches long) in the Estuary; but by the late 1970s there were only about 1 million.

In addition to the reduction in adult bass numbers, young bass abundance had been very low since 1977. This suggested that recruitment to the legal-sized population would continue to be low, and that the adult population would likely remain depressed for several years unless remedial action was taken.

At that time, without the availability of recently developed mathematical models, the DFG hypothesized that the decline in abundance of legal-sized striped bass since 1976 probably reflected reduced survival of adults. Although the analysis was not conclusive, conservative resource management dictated restricting angling regulations to reduce harvest. If no action was taken, fisheries managers feared the fishery would probably continue to be depressed and the time required for recovery would increase. The DFG also believed that in the event that its analysis was incorrect, the more restrictive regulations would still increase adult bass survival, which, in turn would further increase abundance and regulations could be liberalized later to take advantage of that population growth.

Table 9. Striped Bass Harvest in the Sacramento and San Joaquin Rivers, the Delta, and San Francisco Bay (1969-1991).

Year	Percent Harvest	Total Number Legal Size	Catch
1969	17.1	1,646,026	281,470
1970	12.1	1,727,395	209,014
1971	17.1	1,599,716	273,551
1972	17.0	1,882,907	320,094
1973	16.7	1,637,159	273,405
1974	22.9	1,477,213	338,001
1975	24.0	1,849,771	443,945
1976	20.8	1,581,077	328,864
1977	17.0	924,301	157,131
1978	16.3	1,151,643	187,718
1979	15.5	1,155,701	179,134
1980	12.3	1,115,999	137,268
1981	11.0	911,300	100,243
1982	15.9	825,126	131,195
1983	23.7	1,009,748	239,310
1984	22.3	1,048,244	233,758
1985	19.8	1,038,126	205,549
1986	16.3	1,064,142	173,455
1987	15.2	1,037,617	157,718
1988	13.3	967,290	128,650
1989	8.7	873,065	75,957
1990	12.6	677,942	85,421
1991	13.5	799,913	107,988
1992	9.1	624,168	56799
Average	16.26	1,192,733	201,068

The DFG, also believed that a contributing factor in population and recruitment declines was the deteriorating environmental condition of the Estuary. The evidence, in the DFG's view, suggested that the accelerated decline in the abundance of young bass (and subsequent abundance of 3-year-old recruits) after 1976, was probably attributable to a reduction of total egg production resulting from the decline in adult abundance (Stevens et al. 1985). The DFG associated each of these declines with environmental factors in the Estuary related principally to flows and hydrodynamic influence.

In the early 1980s, to reverse the decline of the striped bass fishery, the DFG advocated altering angling regulations, improving environmental conditions in the Estuary, and undertaking a program of artificial propagation of striped bass.

The tightening of angling regulations was expected to achieve at least a 25 percent reduction in catch. This, by itself, was predicted to increase adult populations by 60 to 85 percent in 10 years. In combination with the other actions, the DFG believed that recovery would occur even more quickly.

To achieve the goal of a 25 percent reduction in harvest, season closures, changes in bag limits, and changes in minimum size were considered. The following alternatives were evaluated to accomplish that goal: 1) increase minimum size to 20 inches; 2) reduce limit to one fish; 3) close season for one month in the spring and one month in the fall; 4) increase minimum size to 18 inches; and, 5) various combinations of increasing minimum sizes, reducing bag limits, and imposing fishing closures.

A reasonable immediate goal in managing the striped bass population through changes in angling regulations was to return the population, and the fishery, to the mean level that existed from 1969 to 1974. Quantitatively, that translated to 650,000 spawning females ($\geq$ age 4) providing 290 billion eggs annually and an estimated population of about 1,662,000 legal sized fish.

Under all flow scenarios, the data suggested that there would be little change in the status of spawning stocks with a harvest rate of 17 percent, the average rate from 1976 to 1979. The estimated 25 to 30 percent reduction in harvest rate would cause the spawning stock to increase about 60 to 85 percent (depending on the outflow patterns) in 10 years, but still be 25 to 35 percent below the goal of 650,000 spawners. With a 50 percent reduction in harvest, the goal would be essentially achieved in 10 years with estimated spawning stocks ranging from 87 to 103 percent of the mean 1969-74 level.

Regulations had allowed harvest rates as high as 24 percent in the past. At that level of harvest for the next 10 years, spawning stocks were predicted to decrease 34 to 45 percent. Such a situation was deemed to be highly undesirable. To prevent such a decline, the Fish and Game Commission adopted more stringent regulations in 1982.

Despite an average harvest rate of 15 percent from 1980 to 1991, a reduction from the average 1976-1979 level of 17 percent, the legal sized striped bass population continued to decline (Table 9). Despite harvest reductions in response to the regulation changes, the average population of legal sized striped bass in 1980-91 fell 21.3 percent from that of the 1976-1979 period, to 947,376 fish. The average population in 1990 and 1991 of only 738,928 represented a reduction of 38.6 percent from the 1976-1979 level. These continued declines despite the reduction in harvest rate, support the contention that the decline of striped bass populations are related to factors other than harvest.

Recent Studies

Further recommendations for angling changes were analyzed in 1990. Organized angling groups and others, expressing increased concern about the continued decline in the striped bass fishery, proposed that the DFG evaluate the need for even more severe angling restrictions. The DFG, working with Dr. Louis Botsford of U. C. Davis, completed that evaluation.

The analysis was composed of two stages:

1. Dr. Botsford estimated the relative catch and egg production of a year class over its life span based on size distribution, harvest rate, and natural mortality rate data provided by the DFG.

2. Egg production data was run through a sustained adult abundance model developed by DFG to evaluate the impacts of alternative freshwater outflow and water export levels on striped bass.

The alternative angling regulation changes evaluated were: 1) an increase in the minimum size limit from 18 inches to 24 inches; 2) an increase in the minimum size limit to 28 inches and initiation of a maximum size limit of 38 inches; and, 3) a 5 percent decrease in the harvest rate (which DFG tag return data suggested would result from prohibiting night fishing from boats in Suisun Bay and the Delta).

The first two alternatives would produce substantial changes in catch and egg production. Dr. Botsford's analysis indicated that an increase in the minimum size limit to 24 inches would decrease catch from a year class by 48 percent and increase egg production over the life of that year class by 27 percent. Minimum and maximum size limits of 28 and 38 inches, respectively, would decrease catch by 69 percent and increase egg production by 68 percent. Eliminating night fishing by boat anglers in Suisun Bay and the Delta would result in only a 4 percent decrease in catch and a 4 percent increase in egg production.

The DFG's model was then used to predict population consequences of these changes in egg production. The model predicted adult abundance based on the previous years' young-of-the-year (YOY) abundance and the estimated rate at which young bass are lost at the export pumping plants. YOY abundance is estimated by measuring spring and early summer outflows, exports, and egg production. The export loss rate, after the YOY index is set, is a function of late summer-winter outflows and exports.

Some believe this DFG model may not be an effective tool in determining the potential effects of angling regulations on the Estuary's striped bass population because the harvest was not used as an adjustable variable. However, DFG believes that concern is unwarranted. The procedure itself is used to estimate the effect of a reduction in harvest (and thus a predicted increase in egg production), produced by a particular change in angling regulations. The new egg production data was input to the model in place of the initial adult abundance data and the model then estimated the sustained adult abundance.

The DFG model suggested that the proposed changes in angling regulations would provide minimal benefit to the striped bass population. The model predicted that starting with an abundance of 500,000 legal-sized bass and increasing egg production by 27 percent (equivalent to increasing the minimum legal size to 24 inches) resulted in a stable population of 515,000 legal-sized fish. A 68 percent increase in egg production (resulting from a change to a minimum legal size of 28 inches and maximum legal size of 38 inches) resulted in a stable population of 539,000 adult bass. Since none of the proposed angling restrictions provided a sufficient expectation of increasing the striped bass population, no recommendation was made to further restrict anglers.

The evaluation, however, suggested that conditions in the Estuary, such as levels of outflow and exports, are more important than adult mortality rates associated with harvest in affecting striped bass abundance. The conclusion of the investigation was that managers cannot affect large enough changes in angling mortality rates to have a significant impact on adult abundance at the level of exports and outflow observed in the 1980s and early 1990s (D. Kohlhorst, DFG, pers Comm).

Summary

Measures of mortality rates indicate that approximately 25% of the decline in bass abundance since 1969 is attributed to increased adult mortality. Some of this 25% may result from poaching, but mortality caused by legal sport fishing has not increased as measured by harvest percentage.

DFG analyses have shown additional restrictions on legal sport fishing would result in only small increases in adult abundance. These analyses also show that efforts to reduce the mortality of sub-legal bass would more effectively increase the population.

While poaching has historically been a significant contributor to increased mortality of sub-legal striped bass, the DBEEP appears to be reducing such activity significantly.

Other Perspectives

While many of these techniques have shown some success in managing striped bass populations, some believe that it may also be worth investigating actions to be taken in the Delta, perhaps similar to those taken to restore the striped bass fishery in the Chesapeake Bay (essentially closing the fishery for some limited period which resulted in a rebound of striper populations). (R. Potter, pers. comm.)

Striped bass resource managers, point out, however, that Chesapeake Bay striped bass harvest rates are far higher than those for striped bass in the Estuary and therefore is not an appropriate model to apply to the Delta (P. Chadwick, pers. comm.).

WHITE STURGEON

From the 1860s until 1917 there was a **white sturgeon** commercial fishery in the Estuary. **The** harvest began decreasing after **an** 1887 peak catch of 1.66 million pounds.

In 1901, commercial fishing was halted after less than 200,000 pounds were harvested. Commercial harvest was allowed in 1909, 1916, and 1917, but populations were still low and commercial fishing **of white sturgeon** was **prohibited** entirely in 1917 (Brown 1978).

From 1918 through 1953, it was illegal to take **white** sturgeon by any means in the Estuary. Sport catch of white sturgeon **resumed** in the Estuary in 1954. **This** heavily regulated sport fishery has allowed 1 fish per day with a minimum **legal** length (which has changed several times **over the years)** ranging between 40 and 50 inches. Initially, large numbers of fish were **taken** by party boat anglers trolling to snag the fish. Trolling for white sturgeon was outlawed in 1956, and harvest immediately dropped to a small number of fish caught by anglers fishing for other species. It wasn't until 1964, when it was discovered that shrimp was an effective bait, that the sport fishery increased (Brown 1978). Current sport fishing regulations provide for a 46" minimum legal length, a 72" maximum, and a one fish per day limit (California Sport Fishing Regulations 1994).

Population Size

White sturgeon population dynamics have been monitored intermittently since the sport fishery re-opened in 1954. Tagging studies have been used to estimate abundance, mortality rates, and to determine movement. (Mills and Fisher 1994).

White sturgeon are captured for tagging purposes in the fall in San Pablo Bay **as it provides** ideal conditions for such activity.

White sturgeon abundance was estimated using the Petersen method in years when a recapture sample was available from tagging in a later year(s). When adequate samples were not available, the Schumacher and Eschmeyer method was used, which required multiple censuring and was based on re-captures during **the** same tagging season.

When calculating mean abundance, population estimates were determined by linear interpolation in years when no tagging occurred.

Catch/harvest data **are** estimated from tag returns. A total of 5,952 white sturgeon were tagged with $20 disc-dangler reward tags in 1984, 1985, and 1987. Tagging white sturgeon with reward tags first began in 1967 and 1968 when $5 rewards were offered. This study continued in 1974 and 1979 when $10 reward tags were used. The reward tags were boosted to $20 for added incentive (Mills and Fisher 1994).

White sturgeon population estimates have varied greatly since the fishery re-opened in 1954. The 1954 estimated population of 11,200 legal sized fish increased to 114,700 in 1967 and dropped to 20,700 in 1974. By 1979 the estimated population again had risen to 74,500 fish. It reached its peak in 1984 at 120,000 fish. Subsequent population estimates have declined to 86,000 in 1987 and 29,000 in 1990 (Table 10) ~~(D. Kohlhorst, DFG, pers. comm.).~~ The large swings in population estimates reflect infrequent, high flow candidates and the occurrence of other favorable environmental conditions that boost populations. Population estimates are not yet available for years 1991-1993.

Types of Harvest

The white sturgeon is a native anadromous fish that is growing in popularity as a sport fish. Many white sturgeon are found in Suisun and San Pablo bays throughout the year, although peak fishing activity **occurs** from November through January. In San Francisco Bay, most fish are caught from January through March. In the fall, some of these fish **migrate** up the Sacramento River **to** spawn and concentrate in the upper river near Colusa. White sturgeon also

Table 10. Population Estimates and Estimated Catch of White Sturgeon.

YEAR	ESTIMATED. POPULATION*	CATCH
1954	11,200	200
1967	114,700	8,400
1968	40,000	2,600
1969		
1970		
1971		
1972		
1973		
1974	20,700	1,200
1975		
1976		
1977		
1978		
1979	74,500	16,200
1980		
1981		
1982		
1983		
1984	118,000	11,500
1985	108,000	12,400
1986		
1987	86,000	7,200
1988		
1989		
1990	29,000	900

* Populations were estimated based on marked recapture estimates for the following years. A linear interpolation could be used to estimate populations for non-population estimate years, however, these numbers would be highly speculative.

migrate up the San Joaquin River in the spring, although spawning activity has not been verified as in the Sacramento River.

According to results of tag returns, more than ten times the number of tags were returned from white sturgeon caught in the Sacramento River as in the San Joaquin River (Kohlhorst et al. 1991). The methods of take for anglers fishing in the Estuary include rod and reel fishing from shore and in private and party boats, principally using various types of shrimp for bait, although, sometimes the same types of dead fish baits used for striped bass are also used (Kohlhorst et al. 1991).

Illegal Harvest

Anglers illegally harvest white sturgeon in the Estuary by keeping fish smaller than 46 inches or longer than 72 inches. White sturgeon are also illegally harvested by gillnetters and setliners. Anglers who use gaffs or firearms when they land white sturgeon are also **guilty of** illegal take.

Illegal harvest of **white** sturgeon in the Estuary has not been measured. However, in the last 30 years, the white sturgeon sport fishery has greatly increased in response to improved fishing methods and technology. With more people utilizing the resource and improved success at catch, it appears likely that illegal harvest is also increasing. Although white sturgeon caught illegally are seized by DFG wardens, records of **the** illegal **harvest** are not kept (J. Gonzalez, DFG, pers. comm.).

Sport Fishing Harvest

In San Francisco, Bay more than half the yearly sport harvest of white sturgeon is landed from January through March. Very few fish are caught from August through October due to reduced presence and vulnerability to harvest. The DFG has monitored white sturgeon harvest rates periodically since 1954 (Table 10). Until 1984, harvest rates stayed below 8 percent. Then they rose to nearly 11 percent in 1985. During the mid-1980s the **Estuary's** sport fishery for white sturgeon **was believed to be reaching a level with the** potential to over-exploit the population (Kohlhorst 1993). **Consequently in the late 1980s** the DFG and sport anglers became concerned about increased exploitation rates, declining catch, and the known susceptibility of white sturgeon populations to over-harvest.

A mathematical model was developed to evaluate the effect of angling regulation changes on **white sturgeon** abundance, egg production, and **harvest** over a 30-year period. The goal was to **use this data to develop and** adopt regulations that were socially acceptable, **while** maintaining white sturgeon abundance and egg production at the high levels of the mid-1980s (Kohlhorst 1993).

Based on that initial modelling, minimum size limits of 42-48 inches and a maximum size of 72 inches were recommended to protect **white** sturgeon spawning stock. These new **limits** went into effect March 1, 1990, with the minimum **legal** size to increase from 42 inches by two inches per year until it reached 48 inches. These regulations reduced **legal** harvest to less than 5 percent of the **total estimated** population (Table 10). Based on additional modelling by the DFG, **undertaken** after charter boat operators and bait shop owners **complained** about severe economic hardships, the Fish and Game Commission halted the minimum size limit increase at 46 inches in 1993. The maximum **legal** size allowed **to be taken** remained unmodified at 72 inches.

Effect on Population

Over the past 35 years white sturgeon abundance in the Estuary **has** varied greatly. **This has occurred** primarily **as a result of** variations in recruitment **rates** while the annual harvest rate, a major component of total annual mortality rate, has increased from a mean of 0.069 in the 1960s and 1970s to 0.097 in the 1980s. This 41 percent increase in harvest rate for white sturgeon resulted from the previous mentioned burgeoning popularity of the fishery. **Also** angler sophistication has increased through **the use of** sonar **to locate fish** and use of more effective baits. **An** increase in annual mortality rate **estimates** from 0.16 (survival = 0.84) in 1967 to 0.26 (survival = 0.74) in 1984, **reflects** the **impact** of the expanded **harvest** on the white sturgeon population (Kohlhorst et al. 1991).

Some studies suggest that the variation in recruitment may be a result of fluctuation of high outflows through the Estuary in spring and summer. During peak outflow years, more young white sturgeon are produced (Kohlhorst et al 1991).

Current Regulations and Enforcement Efforts

White sturgeon may not be **harvested** that are shorter than 46 inches or longer than 72 inches. These restrictions protect young **white** sturgeon that have not reached spawning age and allow for increased egg production **by protecting** larger fish. **White** sturgeon have a long life span and **only** reach sexual maturity at approximately 14 years (Kohlhorst et al 1991).

Fishing regulations also prohibit the use of firearms or gaffs in landing **white** sturgeon and **impose a one fish** limit. (California Sport Fishing Regulations, 1994). Also, snagging and trolling is prohibited. White Sturgeon must take anglers, bait willingly.

AMERICAN SHAD

American shad were introduced to the Pacific coast from the east coast of the U.S. to enhance sport fishing opportunities. From 1871 to 1880 American shad were planted in the Sacramento River near Tehama, California. Except for 1976 and 1977, there are no annual population estimates for American shad in Central Valley rivers and streams (Mills and Fisher 1994). American shad population estimates were 3.04 million in 1976 and 2.79 million in 1977.

Types of Harvest

American shad are harvested by anglers in the Sacramento and San Joaquin river systems. Artificial flies, shad darts, and other lures fished with rod and reel are popular methods of take. Bump nets (trolling a chicken wire mesh net in the wake of a slow moving boat) provide another form of harvest. Male shad are caught when they are attracted to motor turbulence and "bump" into the net cone. The angler then flips the shad into the boat (Meinz 1981, Radovich 1970). **For some reason, female shad are not attracted to the turbulence.**

American shad were harvested commercially by gillnetters in the Sacramento and San Joaquin rivers and **in** the Estuary from 1879 to 1957 (Meinz 1981). Annual harvest was about 1 million pounds. The commercial fishery was closed in 1957 to reduce the incidental take of striped bass and salmon.

Means of illegally harvesting American shad include exceeding possession limits (25), and gillnetting. Records are not kept of shad fishing violations (J. Gonzalez, DFG, pers. comm.).

Illegal Harvest

Illegal take is not monitored to an extent that an estimate **of its magnitude** can be made.

Sport Fishing Harvest

Shad angling became popular in the 1950s. Once the sport fishery became established, it grew to a mid- 1960s level of 100,000 angler days fished annually. The Sacramento, American, Feather and Yuba rivers have traditionally been popular with shad anglers (Meinz 1981).

Harvest records for the Sacramento-San Joaquin sport fishery are limited to the years 1976 - 1978 (Meinz 1981) and 1990 - 1993 (L. Wixom, DFG, pers. comm.).

A creel census of the American shad sport fishery in the Sacramento River was conducted from 1976 through 1978 to measure harvest. The survey found that approximately 70 percent of the shad harvested in the Sacramento-San Joaquin Delta bump net fishery came from the lower Sacramento River or the North Fork of the Mokelumne River (Meinz 1981). Annual catch from this region's fishery ranged from 7,200 to 11,600 shad. (Meinz 1981). Anglers **annual shad catch** on the Sacramento, American, Feather, and Yuba rivers **in the years 1976 - 1978** ~~**ranged from**~~ **was 81,670; 79,153; and 140,421 respectively** ~~174,000 to 208,500~~. ~~More than 60~~ Seventy percent of the total American shad recreational catch was from the Sacramento River. (Table 11) (Meinz 1981).

Table 11. American Shad Recreational Catch Estimates (number of fish) for the Sacramento River System 1976-1978 (from Stevens et. al. 1985).

	Recreational Catch		
River	1976	1977	1978
Yuba	800	20	8,900
Feather	20,900	10,100	19,800
American	6,800	2,800	23,100
Sacramento	53,174	66,233	88,621
Total	81,670	79,153	140,421

The most recent harvest data covers a three year period from July 1, 1990 to June 30, 1993. The data **were** collected as part of the DFG Inland and Anadromous Sportfish Management and Research Project. Data **were** collected on salmon, steelhead, trout, sturgeon, striped bass, catfish and American shad along a 400 mile study area of the Sacramento River system. Information collected included species sought, hours fished, fish kept, and fish released (L. Wixom, DFG, pers. comm.). Analysis of the data involved combining, sorting and summarizing individual records and then expanding this data to arrive at estimates of total angler use and harvest. Data collected prior to 1991 **was insufficient to support** any statistical correlation with assured influence factors. (L. Wixom, DFG, pers. comm.).

From July 1, 1990 through June 30, 1991 an estimated 45,900 American shad were caught in the mainstream Sacramento River from the Carquinez Bridge to Redding. Of this total, an estimated 34,000 fish were released ~~(L. Wixom, DFG, pers. comm.)~~ (Table 12).

An estimated 54,700 shad were caught during the reporting period July 1, 1991 through June 30, 1992. Of this total, an estimated 34, 500 shad were released by anglers ~~(L. Wixom, DFG, pers. comm.)~~ (Table 12).

During the reporting period July 1, 1992 through June 30, 1993, an estimated 80,500 American shad were caught by anglers. Of this total, an estimated 50,300 fish were released (Table 12) ~~(L. Wixom, DFG, pers. comm.)~~.

Table 12. Estimates of sport fishing catch of American shad (L. Wixom, DFG, pers. comm.).

YEAR	EST. FISH KEPT	EST. FISH RELEASED	TOTAL
1990-91	11,900	34,000	45,900
1991-92	20,200	34,500	54,700
1992-93	30,200	50,300	80,500

Effect on Population

Historically, shad spawned extensively in the Delta, as well as in the rivers upstream of the Delta. **Today**, spawning is limited to the upper **reaches** of the north Delta. Reduced spring outflows from upstream reservoirs may prevent some juvenile shad from reaching critical nursing areas downstream. Entrainment of fish formerly produced in areas within the influence of water project export pumping may have eliminated some spawning runs to those areas. Entrainment of shad in in-Delta agricultural diversions also may **have an** adverse affect, however, such entrainment also occurred when American shad runs were much larger than at present. Estimates of sport harvest of American shad are low compared to estimated abundance levels and lower than the historic commercial harvest.

LEOPARD SHARK

The leopard shark, also known as "tiger shark" or "cat shark", is valued as a food and game fish as well as for aquarium displays. The extent of the leopard shark fishery is difficult to measure for two reasons: **1)** commercial landings of this species are grouped under the general heading of "sharks unspecified" or "sharks miscellaneous"; **2)** until the beginning of the last decade, statistics on sport catch were very limited (Smith 1992). **It is worth noting that** the leopard shark, compared to other fish discussed in this paper, has a low **reproduction rate (4 to** 29 pups per year).

Types of Harvest

Commercial harvest of leopard shark in San Francisco Bay and other California waters involves **the use of** gillnets and commercial longlines. Gillnetting is allowed along the coast but catches are declining as a result of legislation that limits **this practice**. Bottom trawlers occasionally catch a few leopard sharks **as well** (Smith 1992).

Sport anglers fish for leopard sharks in San Francisco Bay from party boats, private boats, and piers and jettys with hook and line. Anglers use bait such as clams, worms, ghost shrimp, herring, and anchovies, but the principal bait used is the midshipman (Smith 1992). Also, divers spear leopard sharks.

Methods of illegal harvest of leopard sharks include gillnetting in San Francisco Bay, exceeding the 3 fish sport catch limit, or keeping sharks shorter than 36 inches.

Illegal Harvest

Illegal harvest of leopard shark includes the **commercial and sport** take of fish that are shorter than the minimum length **legal** limit of 36 inches. Hook and line angling, gillnetting, longlining, and spear fishing are all methods by which leopard sharks may be taken illegally by possessing more than the 3 fish limit or violating size restrictions.

Sport Fishing Harvest

Sport harvest of leopard sharks is a significant factor **affecting** the total population. **Analysis of** recovery patterns of 948 tagged leopard sharks released in the San Francisco Bay area in 1979 by the NMFS, has shown that roughly 82 percent of the 108 recoveries were returned by sport anglers, while only 18 percent were caught commercially (Smith 1992). In the past ten years, the popularity of the **leopard shad** sport fishery has increased substantially.

Commercial Fishery

Total commercial harvest of leopard sharks in California has ranged from 9,278 pounds (representing less than 1,000 fish) in 1958 to 101,283 in 1983 **(Table 13)**. In the last ten years, the leopard shark catch has been increasing in the south and decreasing from Monterey northward.

Table 13. Leopard Shark Commercial Harvest, California, 1977-1992. Data from Leet, Dewees, and Haugen; California Living Marine Resources and Their Utilization; 1992.

Year	Number of Pounds Harvested
1977	22,267
1978	34,956
1979	38,939
1980	40,085
1981	51,506
1982	70,619
1983	101,283
1984	67,855
1985	75,838
1986	74,741
1987	55,025
1988	41,737
1989	50,167
1990	40,822
1991	47,677
1992	42,257
Average	57,052

D-001263

A legislative ban on inshore gillnetting of leopard sharks in the Monterey Bay/San Francisco Bay area is a likely contributor to the observed decline in Northern California's catch after 1986 (Smith 1992).

Effect on Population

Results of the San Francisco Bay tagging project **(mentioned above)** show that 10 percent of the resident population migrate into the ocean during **the** fall-winter **period.** California's **total** leopard shark population has not been estimated. Catch statistics are currently used to make inferences about stock abundance. However, this method of measuring stock abundance may not be reliable since **some** evidence points to environmental conditions that may affect the population.

Increased commercial and sport harvest of leopard sharks have been recorded in the San Francisco Bay area in **years when** Delta outflow **is high**. Tagging results **indicate this increase is** not attributable to immigration of sharks from other areas (Smith 1992). The implication of this observation is that if the local population is over harvested, recruitment from other populations is unlikely or will be slow.

Because of the leopard shark's increasing popularity as a game fish and its low **reproduction rate**, the DFG **believes** this species should be monitored closely to ensure **against** over-fishing adversely affecting its abundance.

Current Regulations and Enforcement Efforts

The leopard shark has a very slow growth rate of (less than 1 inch/year), a late sexual maturity, produces comparatively few young, and is a favorite species in the commercial aquarium trade. It is for these reasons that the California Fish and Game Commission instituted a 36 inch minimum legal length for the take of leopard shark (California Sport Fishing

Regulations 1994). California's 1994 sport fishing regulations **also** limit anglers to possession of no more than 3 fish.

PACIFIC HERRING

Pacific herring is a marine fish that spawns in bays and estuaries. San Francisco Bay is the largest and most productive **herring** spawning area in California. The herring's spawning cycle appears to be related to high tides. Approximately 88 percent of herring spawning occurs when the tide cycle is highest at night (Spratt 1981).

California's Pacific herring fishery **began** in 1972 **to serve** Japan's growing market for herring roe. When the fishery began, there was little available information on California's herring stocks. The DFG began annual population assessment surveys in the mid 1970's to develop a management plan (Spratt 1992).

While this management plan was being completed, the California State legislature set quotas for the fishery. The Fish and Game Commission undertook management **responsibility for** the fishery **beginning with** the 1973-74 season. In 1977, a limited permit program was adopted for Tomales and San Francisco bays, the largest herring fisheries, with San Francisco Bay **users** receiving the majority of the permits (Spratt 1992).

Types of Harvest

Herring are fished commercially in San Francisco Bay using round haul gear such as lampara nets, purse seines, gillnets, and bait nets. In 1991, gillnetting was banned in a large section of San Francisco Bay, between the Bay Bridge and Hunter's Point. In those areas, premature spawning in deep water or on the nets was resulting when herring gathered in large numbers prior to spawning and gillnets were used (Spratt 1992).

Illegal harvest of Pacific herring **includes** fishing in closed areas, **using** prohibited gear, or fishing outside of open fishing **seasons**. Exceeding quota allocations for a particular type of gear or for a specific area are also **components** of illegal take.

Illegal Harvest

Presently, there **are** no data regarding the extent of the illegal harvest **of herring**.

Commercial Fishery

California's two most important herring spawning grounds, Tomales and San Francisco bays, **support** two separate and **distinct** spawning stocks that are managed to ensure that each is not over fished. DFG annual herring biomass estimates for both bays are determined by conducting hydro-acoustic and/or spawning ground surveys (Spratt 1992, Wendell and Oda 1990). Harvest quotas are usually set at approximately 15 percent of the total annual herring biomass estimates from each bay. Area quotas are set independently, and vary according to annual herring biomass **measurements** in each bay (Spratt 1992).

The DFG has kept harvest records for the San Francisco Bay herring fishery since 1972. Seasonal harvest, recorded in tons landed, includes herring and herring roe attached to kelp. (Table 14) ~~(Spratt 1992)~~.

Table 14. Commercial Herring Landings 1972-1993 (Spratt 1992).

SEASON	QUOTA	CATCH HERRING & ROE (IN TONS)	AVERAGE % ROE	TONS LANDED HERRING ONLY
1972-73	1,500	436	12.2	383
1973-74	500	1,938	12.2	1,702
1974-75	600	514	12.2	451
1975-76	3,050	1,719	12.2	1,509
1976-77	4,000	4,201	12.2	3,688
1977-78	5,000	4,987	12.2	4,379
1978-79	5,000	4,121	12.2	3,618
1979-80	6,000	6,430	12.2	5,646
1980-81	7,250	5,826	12.2	5,115
1981-82	10,000	10,415	12.2	10,288
1982-83	10,399	9,695	12.2	9,577
1983-84	10,399	2,838	12.2	2,492
1984-85	6,500	7,740	12.2	6,796
1985-86	7,530	7,278	12.2	6,390
1986-87	7,530	8,098*	-	8,098
1987-88	8,500	8,741*	-	8,741
1988-89	9,500	9,736*	-	9,736
1989-90	9,057	8,962*	-	8,962
1990-91	8,858	7,741*	-	7,741
1991-92	7,134	7,417	12.2	6,512
1992-93	5,386	5,151	12.2	4,523
1993-94	2,009	2,300	12.2	2,019

* Herring only, roe on kelp is not included.

Effect on Population

Commercial harvest of pacific herring does not appear to have a significant effect on the population's ability to maintain itself. During the past 20 years, there have been three El Ninos: 1976, 1983 and 1992 through 1993. The warmer ocean temperatures **associated with El Nino** reduce the number of fish migrating to their spawning grounds. Since catch quotas are set according to spawning biomass of the previous season, quotas **reflect this** reduced spawning stock (C. Ryan, DFG, pers. comm).

Current Regulations and Enforcement Efforts

The majority of San Francisco Bay was off limits to encircling nets (Purse seine, lampara, beach nets) for many years to protect Pacific herring, salmon, striped bass, sturgeon and shad. Bait nets, made of purse rings and seine twine, had been allowed for the harvest of bait fish only (Spratt 1992).

Beginning in 1979, the Fish and Game Commission ruled that lampara nets qualified as bait nets and this began a ten year period during which more of San Francisco Bay opened to round haul gear, first lampara, and in 1989-90 purse seines for commercial herring fishing (Spratt 1992). To prevent take of sport fish (sturgeon, striped bass, sturgeon), a rigid metal grate of parallel bars no more than 3 inches apart is placed over the hatch while dumping **herring** into the hold so that the sport fish **will** be deflected onto the deck and **can be returned** to the bay.

Transfer of herring between vessels or permit holders is prohibited in order to keep groups of vessels from fishing together and to prevent **commercial** fishermen from circumventing gear quotas and vessel allocations (Spratt 1992).

Starting with the 1991-92 season, the central part of San Francisco Bay, between Hunter's Point and the Bay Bridge, was closed to gillnet fishing to protect **this** important spawning area.

LARGEMOUTH BASS

The largemouth bass is **a non-native** warm water fish that can be found in nearly all suitable lakes, sloughs and slow moving rivers in California. In the late 1800s, 22 **large- mouth** bass **from the east coast** were planted in Crystal Springs Reservoir in San Mateo County (Seymour 1979).

Types of Harvest

Anglers fish for largemouth bass in the Estuary and the Sacramento and San Joaquin rivers with rod and reel. Typically, artificial lures are cast or trolled, although earthworms, grasshoppers, crickets, minnows, and artificial flies may also be used (Robbins and MacCrimmon 1974).

The extent of the illegal take of largemouth bass has not been monitored in the Delta. Illegal harvest generally involves **anglers exceeding take** limits taken and fish **taken** by gillnetters, although largemouth bass are **generally** not very susceptible to gillnets (J. Gonzalez, DFG, pers. comm.).

Illegal Harvest

The level of illegal take of largemouth bass in the Delta has not been determined. Since there is a possession limit of five fish, with no size restrictions, and largemouth bass are not very susceptible to gillnets, illegal take tends to be limited to over limits by anglers. The DBEEP has helped reduce the illegal take of largemouth bass.

Sport Fishing Harvest

There is very little information available concerning harvest rates and population size of largemouth bass in the Sacramento and San Joaquin rivers. The most recent harvest data are confined to **that collected from** largemouth bass tournaments, conducted in the Delta from 1985 through 1993. This information is limited to completed tournament harvest data reports as of March 21, 1994. An additional 10-20 percent of the tournament **data reports** have not yet been **analyzed** (I. Paulsen, DFG, pers. comm.).

Largemouth bass tournament data lists the number of fish caught, including the number that died after being landed. Largemouth bass tournaments release live fish after weights and/or numbers of fish have been recorded. Tournament catch ranged from 78 fish caught during a single fishing day in 1985 to 15,546 recorded during 110 tournament days in 1992. Largemouth tournament data for 1993 are incomplete. The total 1993 catch recorded as of March 21, 1994 stands at 15,270 fish caught during 126 angling days (Table 15) ~~(I. Paulsen, DFG, pers. comm.)~~.

Largemouth tournament catch data includes the take of largemouth and smallmouth bass as well as redeye and spotted bass. The largemouth bass portion of the total tournament catch is not available so the most accurate measurement of largemouth bass harvest in the Sacramento-San Joaquin Delta would be the 30 percent harvest rate measurements recorded during 1980 through 1984. The DFG believes that the harvest rate has not changed appreciably during this period in relation to increased angler participation, improved angling efficiency, or increasing numbers of tournaments.

Effect on Population

The estimated annual harvest of no more than 30 percent in the Delta, based on tagging studies done in the mid-1980s, is less than that of many other largemouth bass populations which are known to be stable. Thus, the DFG **believes** that the sport take is well within acceptable levels.

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Table 15. Largemouth Bass Tournament Catch, Sacramento-San Joaquin Delta, 1985-1993 (I. Paulsen, DFG, pers. comm.).

Year	Catch
1985	78
1986	1,811
1987	2,657
1988	4,990
1989	5,592
1990	10,195
1991	10,924
1992	15,546
1993	15,270

Current Regulations and Enforcement Efforts

Current California sport fishing regulations for the Sacramento-San Joaquin Delta allow anglers to take largemouth bass all year. There is a possession limit of 5 fish, but no size restrictions (California Sport Fishing Regulations, 1994).

APPENDIX A

D-001272

GLOSSARY

Adjusted Peterson Population Estimate — Also called the single census method, fish are marked only once; subsequently a single sample is taken and examined for marked fish. The marking should be restricted to a short period of time but the sampling that follows may occur over long period.

Anadromous — Migrating up rivers from the sea to spawn in fresh water.

Bump Net — A long handled chicken-wire dip net is fished in the prop-wash of a slow moving boat. When a shad bumps the net, the "bumper" quickly attempts to flip the fish into the boat.

Creel Census — A survey of boat and/or shore sport anglers to record the number and species of fish caught as well as other biological data necessary to manage a fishery.

Escapement — The number of fish that escape the fishery and return to spawn.

Exploitation Rate — The number of fish that are taken in the sport angler or commercial harvest compared to the fish that escape to spawn.

Harvest — Taking fish for sport or commercial purposes.

Harvest Rate — That part of the population that is taken by the legal or illegal fishery.

Illegal Harvest — Taking more fish than is legally allowed, taking fish during a closed season, or with illegal gear.

Jolly-Seber Population Estimate — $B_i = \frac{\underline{M_i K_i}}{R_i} + M_i$

B_i = the # of marked fish in the population
M_i = new marked fish just released
K_i = the sum of all recaptures made later than time of $_i$ of fish marked before time $_i$

Lampara Net — An encircling net that is shaped like a dustpan and has wing-like attachments on each side. The net bag is made of small meshed netting and the wing attachments are made of coarse material with wider meshes.

Mortality Rate — The number of deaths from a certain cause in a unit of population over a certain period of time.

Party Boat — A fishing vessel that carries sport anglers who have paid a fee for a day or more of fishing.

PFMC — Pacific Fishery Management Council.

Purse Seine — A surrounding net that surrounds fish not only vertically but horizontally. Seines have long walls of netting with a leadline of equal length or longer than the floatline. This seine has oval rings hanging at lower edge of the gear with a mechanism that opens the rings to form a purse shaped mouth opening. A line runs through these rings so that when the rope is tightened the seine will close.

Recruitment — The number of fish that are added to the adult population each year.

Recruitment Curve — See Appendix A

Redd — A hollowed out depression in the gravel of a river or stream that is excavated by a female salmon prior to depositing her eggs.

Round Haul Gear — Refers to purse seines and lampara nets.

Schaefer Population Estimate —

M_i = number of fish marked in the *i*th period of marking (Ta of Schaefer)
$M = \sum M_i$, total number marked
C_j = number of fish caught and examined in the *j*th period of recovery (Ma_i of Schaefer)
$C = \sum C_j$, total number examined
R_{ij} = number of fish marked in the *i*th marking period which are recaptured in the *j*th recovery period
R_i = total recaptures of fish tagged in the *i*th period (Ma of Schaefer)
R_j = total recaptures during the *j*th period (M_i of Schaefer)

$$N = \sum Nij = \sum R_{ij} \cdot \frac{M_i}{R_i} \cdot \frac{C_j}{R_j}$$

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Schumacher and Eschmeyers Population Estimate	$\frac{1}{N} = \frac{\sum(M_t R_t)}{\sum(C_t M_t^2)}$	N = population estimate M_t = total marked fish at large at the start of the *t*th day, i.e. the number previously marked less any accidentally killed at previous recaptures.

$M = \sum M_t$, total number marked
C_t = total sample taken on day t
R_t = number of recaptures in the sample C_t
$R = \sum Rt$, total recaptures during experiment

Smolt — A juvenile salmon that has undergone physiological changes that allow it to successfully migrate into salt water.

Trammel Nets — A type of entangling net which has three net walls. The outer walls consist of wide mesh netting that is stretched tight around an interior loose net that surrounds a fish and entangles it.

PERSONAL COMMUNICATIONS

Date	Name	Title	Project
3-17-94 5-18-94	Baracco, Alan	Senior Biologist	Ocean Salmon Project, DFG
3-17-94	Boydstun, L. B.	Program Manager	Ocean Salmon Project, DFG
3-21-94	Dixon, Richard	Associate Biologist	Ocean Salmon Project, DFG
4-27-94	Fisher, Frank	Associate Biologist	Central Valley Salmon and Steelhead Project, DFG
3-17-94	Flemming, Kevin	Marine Biologist	San Francisco Bay Study, DFG
3-17-94 5-25-94	Gonzalez, Joseph	Lieutenant	Wildlife Protection Division (DBEEP), DFG
3-18-94 5-23-94	Kohlhorst, David	Associate Biologist	Adult Striped Bass and Sturgeon Project, DFG
9-15-94	Kier, William	William Kier Associates	
3-17-94	Maxwell, Bill	Senior Biologist	Sport Fish Restoration Act Coordinator, DFG
3-18-94 DFG	Meyer, Fred	Associate Biologist	Fisheries Management, Region 2,
3-24-94	Oda, Ken	Marine Biologist	Pacific Herring Project, DFG
3-18-94	Paulsen, Ivan	Associate Biologist	Reservoir Project, DFG
9/15/94	Potter, Robert	Chief Deputy Director,	Department of Water Resources
3-25-94	Ryan, Connie	Associate Biologist	Pacific Herring Project, DFG
3-25-94	Roper, Gail	Biologist	Pacific States Marine Fisheries Commission
3-25-94	Schultz, Donald	Senior Biologist	Marine Resources, DFG
3-25-94	Spratt, Jerome	Associate Biologist	Pacific Herring Project, DFG

3-22-94	Wixom, Lynn	Associate Biologist	Sacramento River Angler Survey, DFG
3-25-94	Watters, Diana	Associate Biologist	Sea Otter Project, DFG

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APPENDIX B

APPENDIX B

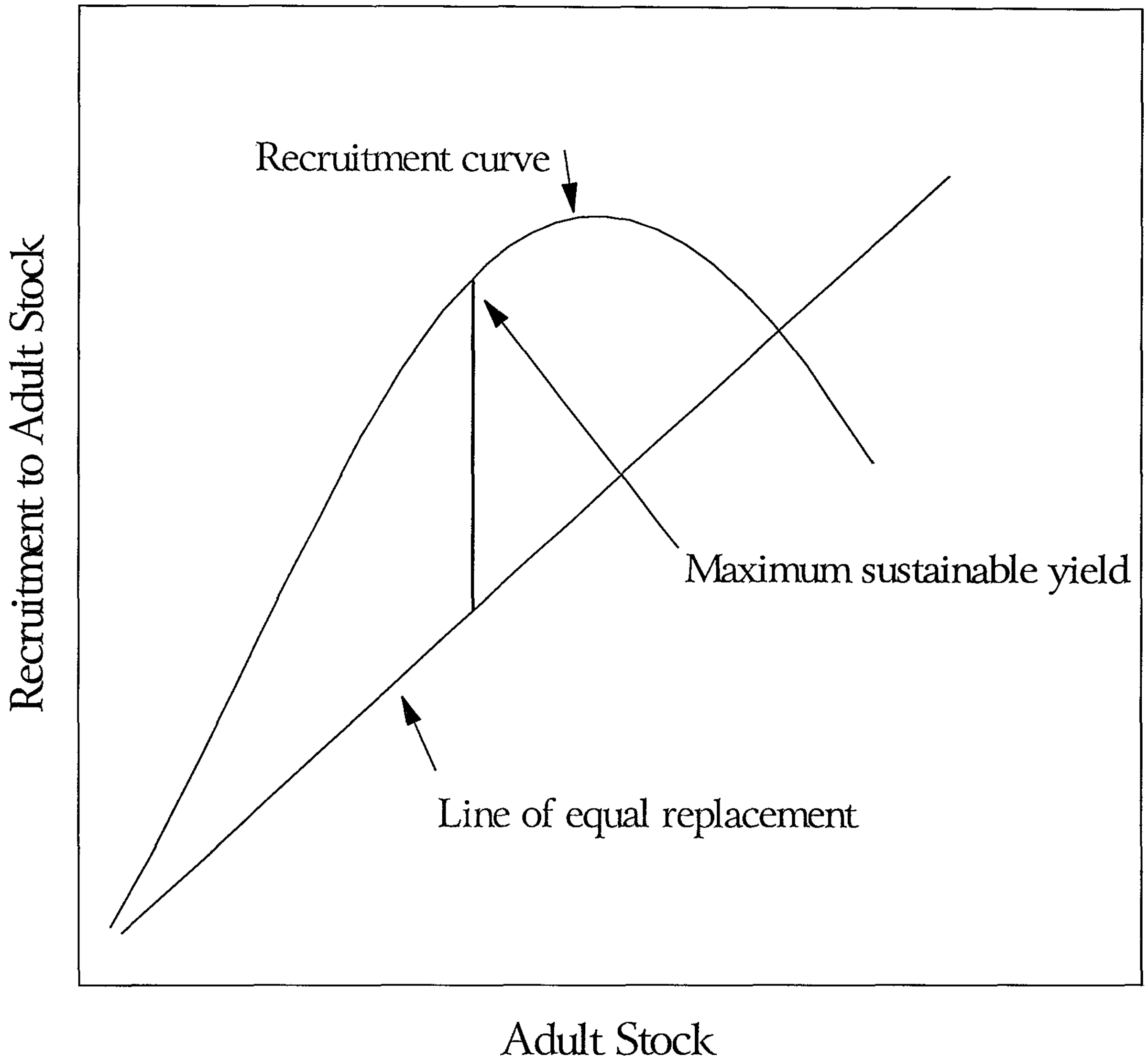
Recruitment is the addition of new members to the population being considered . In a fishery, recruitment refers to the fish that become vulnerable to fishing gear at a stage in their life history (Everhart et al. 1975). Curves depicting recruitment show the theoretical relationship between numbers of adult fish and numbers of fish that become adults (Figure 1) (Ricker 1968).

Reproduction or recruitment curves are developed by taking into consideration that the number of young fish that survive to reach adult size depends on the size of the population of adults and young. A large population of young would experience a greater loss in numbers due to predation, and reduced availability of food.

During years when fewer young were produced, a greater number of young would be expected to survive due to reduced predation and greater availability of food. Factors that affect survival of fish populations regardless of size are floods, droughts, pollution and extreme water temperatures during important times in the salmon's life cycle. Reproduction curves show a population that increases or decreases over long periods of time due to factors that affect a salmon population to a greater or lesser extent depending on how large the population is (Cushing 1968).

The reproduction curve would therefore have a dome shape. The left side of the dome would show a greater number of young surviving than the parents that produced them while the right side of the dome showed a decrease in the number of young being produced. There would be a point on the right side of the dome where the total number of salmon lost to the population equaled the total number of salmon recruited or added to the population due to production of young. This is the point of maximum sustainable yield.

Figure 1.


Recruitment curve
Maximum sustainable yield
Line of equal replacement
Recruitment to Adult Stock
Adult Stock